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Trace Metals in Fish and Shellfish from Scottish Waters

Scottish Fisheries
Research Report
Number 60 1997
ISSN 0308 8022

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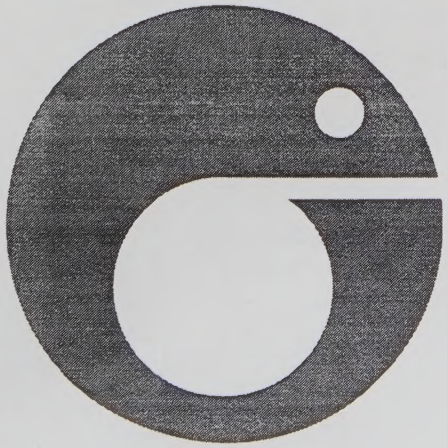

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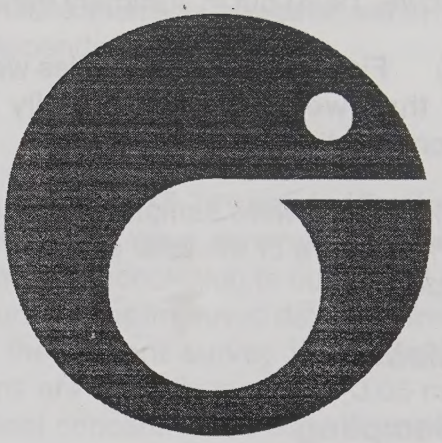
Trace Metals in Fish and Shellfish from Scottish Waters



F M J Brown and P W Balls,
SOAEFD Marine Laboratory, Aberdeen

Introduction

Most of the fishing industry in the United Kingdom is based in Scottish waters. In 1994, some 458 thousand tonnes of fish and shellfish worth 278 million pounds were landed by UK boats at Scottish ports (SOAEFD, 1996). This constitutes 71% of the total UK catch by weight and 61% by value. Of particular importance are landings of pelagic fish such as herring and mackerel, 85% of which were landed at Scottish ports. The Marine Laboratory directs a substantial effort towards monitoring the abundance, behaviour and health of these fish stocks. Part of this work involves assessment of the biological and chemical quality of the marine environment and the effects of changes in quality on fish stocks. Monitoring of the concentrations of contaminants in the marine environment is also undertaken to supply data to national and international baseline studies such as the Joint Assessment and Monitoring Programme (JAMP) of the Oslo and Paris Commissions and the United Kingdom National Monitoring Plan. Of special importance are the concentrations of trace metals in fish and shellfish, information on which is of direct use to Scottish exporters in demonstrating the quality of their product. A major survey of trace metals in fish and shellfish landed at Scottish ports was completed in 1975-76 (Davies, 1981). More recently monitoring effort has been focussed on mercury for which there was a requirement to produce annual data in support of export certificates.

Recent changes in the requirements for export certificates, coupled with a general requirement to update the information from the mid 70s, resulted in a decision to revise the monitoring programme (Balls and Rowe, 1994). This decision was in response to two pieces of UK legislation, the Food Safety (Live Bivalve Molluscs and other Shellfish) Regulations (1992) and the Food Safety (Fisheries Products) Regulations (1992), which were in turn a consequence of EU legislation. As a consequence of these revised regulations member states no longer require Export Health Certificates (including mercury certificates for which the Marine Laboratory provided data). At present certificates for trace metals and other contaminants are only issued where products are being exported to third countries, ie countries outwith the Union. This report presents the results of the revised monitoring programme and is intended to be a sister report to that published earlier on organochlorines in fish and shellfish from Scottish waters (Kelly and Campbell, 1994).

Sampling Strategy

The principal use of the data from this survey was an assessment of possible hazards to human health. The sampling scheme was therefore designed to ensure that commercially important species and fishing areas were included. The sampling criteria for species and areas are described fully elsewhere (Balls and

Rowe, 1994) but in summary they were:

a) Fish and shellfish species were sampled if they were caught primarily for human consumption

b) Areas were sampled if they represented 5% or more of the total catch for a particular species.

Methods

Sampling

Sampling was carried out between 1993 and 1995 and target species and areas are summarised in Table 1. This Table provides information on the completeness of the survey and also, where additional samples were obtained, Figure 1 indicates the fishing areas. The sampling procedure in each area varied between species. For fish, a target number of at least five individuals of marketable size from each area was adopted. For *Nephrops*, tails from 25 large and 25 small animals were homogenised as separate samples. Queen scallop, oyster and mussel samples consisted of pooled and homogenised edible parts.

A fillet of most species of finfish was taken from the bone, with the exception of the angler, where a portion of the tail muscle was removed and chopped. A sub-sample of the chopped fillet was taken and stored at -20°C in polypropylene jars prior to analysis.

Digest Method

The fish and shellfish samples were thawed and digested with hot concentrated nitric acid to obtain release of metals. The quality of the analysis was monitored by ensuring that blanks were acceptable and also by the inclusion of a Certified Reference Material (CRM) in each batch of analysis. DORM-1 from the National Research Council of Canada was used as the CRM in this work.

Quantification

All determinations were made using atomic absorption techniques, Flame for Zn and Cu, Graphite Furnace for Pb, Cd and As, Cold Vapour for Hg.

Quality Control

The summary at the bottom of this page demonstrates that the mean results of the analysis of DORM-1 fell within the certified ranges.

Results

The concentrations (mg/kg wet weight) of trace metals (copper, zinc, cadmium, lead, arsenic and mercury) in the fish and shellfish samples and the areas where they were caught are tabulated in Tables 2-23. Although a comparison of trace metal concentrations in the same species between different areas was not a main objective of the present survey, Tables 2-23 contain area-specific information which could be used to answer more local queries. Table 24 summarises, for each individual species, the range and mean trace metal concentrations from all areas. It is Table 24 which should be used to answer general enquiries on trace metal concentrations in fish and shellfish from Scottish waters.

DORM-1	Cu	Zn	Pb	Cd	As	Hg
Certified value (mg/kg)	5.22	21.3	0.40	0.086	17.7	0.798
±	0.33	1.0	0.12	0.012	2.1	0.074
Mean result (this study)	5.06	21.2	0.36	0.082	15.5	0.730
Number of determinations	7	10	8	13	3	7
Std dev	0.19	0.85	0.07	0.007	1.67	0.060

Discussion

This report represents the most complete survey of trace metal concentrations in fish and shellfish from Scottish waters since that undertaken in 1975-76 (Davies, 1981). A total of 23 fish and shellfish species are included, over 750 samples having been analysed.

In the period since the publication of the earlier report, considerable advances have been made in analytical methods, which have enabled detection limits to be lowered, notably for Pb and Cd. Application of the reduced detection limits to this survey has improved our knowledge of trace metal concentrations in some species although a considerable proportion of the Cd and Pb data are still reported as "less than" values.

The guidelines against which the trace metal concentrations reported here can be assessed are summarised in the Appendix.

Cadmium

Cadmium concentrations in fin fish were all below 0.02 mg/kg, which is consistent with the earlier survey for which this was the detection limit. The results of the present survey indicate that typical concentrations are at least an order of magnitude lower, ie <0.002 mg/kg. Cadmium concentrations in shellfish were higher than those in fish, which is normal. The maximum concentration observed was in scallop (0.26 mg/kg); this concentration was, however, well below the proposed maximum in the Food Safety Regulations (1.0 mg/kg).

Copper

In the majority of species concentrations ranged from <0.02-0.50 mg/kg. In fatty fish , ie herring and mackerel, concentrations were higher and ranged from 0.50-1.27 mg/kg. As with cadmium the highest concentrations were observed in shellfish, the maximum concentration being observed in oysters (0.9-16 mg/kg). The sample size for this species was small, however (two samples), and the upper end of the range may not be representative of typical concentrations. The maximum concentration was, however, within the guidelines (Appendix).

Lead

The previous survey (1975-76) reported that lead concentrations in fish were generally less than 0.1 mg/kg and this conclusion is confirmed by the present survey. The improved detection limits available in the current survey indicate that concentrations are typically less than 0.05 mg/kg. The highest concentrations were observed in shellfish (up to 0.8 mg/kg in mussel). All concentrations are, however, well below the guidelines in the Appendix and the proposed limits in the Fisheries Products Directive for fish (0.5 mg/kg) and shellfish (2 mg/kg).

Zinc

Concentrations in fish were very similar to those reported in the earlier survey. Mean concentrations reported here are all less than 10 mg/kg, well below the guideline level of 50 mg/kg (see Appendix).

Concentrations in shellfish were consistently higher but also extremely variable. With the exception of the small, and possibly unrepresentative, sample of oysters, mean concentrations were less than 100 mg/kg. The guidelines in the Appendix indicate that "higher levels are permitted in food which naturally contains more than 50 mg/kg such as shellfish".

Mercury

None of the mean mercury concentrations in the fish and shellfish species examined exceeded the 0.5 mg/kg maximum contained in the EC Directive (see Appendix). There were a few individual samples of dogfish, however, which did exceed this figure but not the 1 mg/kg limit designated for "other species". Mercury concentrations in fish are known to be a function of several factors, including age, diet, sex, reproductive state and exposure to contamination (Clark and Topping, 1989). The effect of diet is evident in the contrasting concentrations in herring and dogfish (Table 24). Herring are pelagic plankton feeders and contain low levels of mercury, whereas dogfish are

scavengers and accumulate quite high levels of mercury.

For some species, mercury data are available for many of the years between the 1975-76 survey and the present survey (see Introduction). These data can be used to examine the longer term picture of mercury concentrations. The data have been plotted for two species, angler and *Nephrops*, Figures 2 and 3 respectively. These plots indicate that there are no clear changes over time and that mean mercury concentrations have been, and remain, well below the EC limit of 0.5 mg/kg.

Arsenic

Arsenic was only included in the latter stages of the scheme and the data set is consequently smaller. In the absence of specific guidelines for limits on arsenic in fish and shellfish, a comparison can be made with previously published data (Davies, 1981; Falconer *et al.*, 1983). The concentrations reported here are in broad agreement with those in the earlier publications. The mean concentrations in round fish were 1.18-8.71 mg/kg, in flat fish they were higher at 4.3-12.2 mg/kg.

Conclusions

The data presented here have been compared with the standards and guidelines for trace metals in fish and shellfish summarised in the Appendix. It is concluded that exporters should have few problems in demonstrating to their customers that their products comply with the standards and guidelines. The data contained in this report, summarised in Table 24, is of direct use to Environmental Health Officers and others in providing information to the exporters.

Acknowledgements

SOAEFD Freshwater Fisheries Laboratory, Faskally, Pitlochry, for analysis of lead, copper, zinc and cadmium in the 1993 samples. Craig Davis coordinated the field collection of fish samples, Laura McRae collated the results of the chemical analysis.

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Table 1 Species and areas targeted for sampling

Species	Sampling area															
	Viking	Forties	Central	Shetland	Orkney	Buchan	Moray Firth	Forth of Forth	Faroe	North Minch	South Minch	Clyde	Solway	Irish Sea	Hebrides	Rockall
Angler		●		●	●	●				●	❖					
Catfish	●	●	○	●		●										
Cockles				○	○	○				○		○			○	
Cod	○	●	●	●	❖	●				●					❖	
Crab				○						○	○				○	
Dogfish		❖	❖	●	●	○				●	●				●	
Haddock	●	●	●	●	●	●	❖			●						
Hake				●						●	●	●			●	
Herring										❖	❖	❖				
Ling	●	●		●						●	❖					
Lemon sole		●	●	●		●	❖			●						
Mackerel	●			●						●					○	
Megrim				●	●					○	●				●	
Mussel					❖		●			❖	❖				❖	
Norway lobster		○				○		○		●	●	●				
Oyster										❖	❖	❖				
Plaice		●	●	●	●	●				○						

Species	Sampling area															
	Viking	Forties	Central	Shetland	Orkney	Buchan	Moray Firth	Forth of Forth	Faroe	North Minch	South Minch	Clyde	Solway	Irish Sea	Hebrides	Rockall
Queen scallop													○	○	❖	
Saithe	●	●		●						●				○		
Scallop				●		●					○	●		○		
Skate				●	●	●				●					○	
Squid				○	○	○				●		❖			●	
Torsk	●	❖		○												●
Turbot	○	●	●	●		●				❖						
Whiting	●	●	●	❖		●				●	❖					

● Fit the sampling criteria and samples obtained
○ Fit the sampling criteria but no samples obtained
❖ Do not fit the sampling criteria but samples obtained

Table 2 Metal concentrations in **Angler** (*Lophius piscatorius*) from individual areas (mg/kg wet weight)

	Forties	Shetland	Orkney	Buchan	North Minch	South Minch
Cadmium						
Mean	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
n	4	10	5	4	5	10
Std dev	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-0.001	<0.001-<0.001	<0.001-<0.001
Copper						
Mean	0.03	0.02	0.27	0.09	0.03	0.04
n	4	10	5	4	5	10
Std dev	0.03	0.03	0.46	0.05	0.03	0.06
Range	<0.02-0.08	<0.02-0.70	<0.02-1.20	0.04-0.17	<0.02-0.07	<0.02-0.14
Lead						
Mean	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
n	4	10	5	4	5	10
Std dev	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Range	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02
Zinc						
Mean	5.66	3.78	3.67	4.71	4.34	3.66
n	4	10	5	4	5	10
Std dev	2.18	0.51	0.30	0.50	0.55	0.20
Range	3.77-9.34	3.12-4.81	3.30-4.12	4.10-5.47	3.78-5.07	3.39-4.10
Mercury						
Mean	0.06	0.06	0.06	0.04	0.09	0.06
n	7	10	5	9	5	10
Std dev	0.01	0.02	0.02	0.02	0.01	0.02
Range	0.04-0.08	0.02-0.11	0.04-0.09	0.01-0.08	0.07-0.10	0.02-0.09

Table 3 Metal concentrations in **Catfish** (*Anarhichas lupus*) from individual areas (mg/kg wet weight)

	Viking	Forties	Shetland	Buchan
Cadmium				
Mean	<0.001	<0.001	<0.001	<0.001
n	8	9	1	5
Std dev	<0.001	<0.001		<0.001
Range	<0.001 -<0.001	<0.001 -<0.001	<0.001-<0.001	<0.001-<0.001
Copper				
Mean	0.24	0.20	0.11	0.16
n	8	9	1	5
Std dev	0.06	0.05		0.03
Range	0.14-0.32	0.13-0.29	0.11-0.11	0.13-0.19
Lead				
Mean	0.02	<0.01	<0.01	<0.01
n	8	9	1	5
Std dev	0.05	0.01		0.01
Range	<0.01-0.16	<0.01-0.02	<0.01-<0.01	<0.01-0.01
Zinc				
Mean	8.63	7.48	5.08	7.49
n	8	9	1	5
Std dev	1.11	1.57		0.94
Range	7.20-10.33	5.46-10.26	5.08-5.08	6.30-8.70
Mercury				
Mean	0.11	0.12	0.15	0.05
n	8	9	1	4
Std dev	0.06	0.11		0.03
Range	0.05-0.23	0.03-0.39	0.15-0.15	0.02-0.09
Arsenic				
Mean	6.23	7.39	2.67	5.74
n	8	9	1	5
Std dev	1.07	1.40		1.43
Range	5.20-8.10	4.50-9.18	2.67-2.67	4.24-8.19

Table 4 Metal concentrations in **Cod** (*Gadus morhua*) from individual areas (mg/kg wet weight)

	Forties	Central	Shetland	Orkney	Buchan	North Minch	Hebrides
Cadmium							
Mean	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
n	10	10	10	3	10	10	5
Std dev	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001
Copper							
Mean	0.09	0.16	0.12	0.04	0.12	0.12	0.07
n	10	10	10	3	10	10	5
Std dev	0.04	0.09	0.05	0.04	0.05	0.05	0.03
Range	0.02-0.16	0.06-0.36	0.07-0.21	<0.02-0.09	0.05-0.23	0.06-0.23	0.02-0.10
Lead							
Mean	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
n	10	10	10	3	10	10	5
Std dev	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Range	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02
Zinc							
Mean	3.72	3.57	3.91	3.68	3.79	3.57	3.34
n	10	10	10	3	10	10	5
Std dev	2.00	0.68	0.28	0.41	0.64	0.28	0.47
Range	2.99-9.19	2.95-5.11	3.52-4.33	3.11-3.99	3.23-5.40	3.12-4.23	2.93-4.16
Mercury							
Mean	0.18	0.17	0.04	0.03	0.17	0.05	0.06
n	10	10	9	3	10	10	5
Std dev	0.04	0.12	0.01	0.01	0.07	0.02	0.02
Range	0.06-0.19	0.08-0.42	0.02-0.06	0.02-0.03	0.06-0.27	0.03-0.09	0.04-0.08

Table 5 Metal concentrations in **Dogfish** (*Squalus acanthias*) from individual areas (mg/kg wet weight)

	Forties	Central	Shetland	Orkney	North Minch	South Minch	Hebrides
Cadmium							
Mean	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
n	2	4	7	2	5	5	10
Std dev		<0.001	<0.001		<0.001	<0.001	<0.001
Range	0.001-0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001
Copper							
Mean	0.22	0.15	0.79	0.18	0.16	0.27	0.19
n	2	4	7	2	5	5	10
Std dev		0.09	0.30		0.06	0.05	0.08
Range	0.21-0.22	0.03-0.29	0.42-1.22	0.12-0.23	0.10-0.27	0.20- 0.34	0.07-0.34
Lead							
Mean	0.02	<0.02	<0.01	0.01	<0.02	<0.02	<0.02
n	2	4	7	2	5	5	10
Std dev		<0.02	0.01		<0.02	<0.02	<0.02
Range	0.01-0.03	<0.02-<0.02	<0.01-0.01	<0.01-<0.01	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02
Zinc							
Mean	3.34	3.19	2.73	7.01	3.17	3.09	3.79
n	2	4	7	2	5	5	10
Std dev		0.57	0.87		0.37	0.23	1.08
Range	3.32-3.35	2.80-4.18	1.61-4.33	3.55-10.47	2.65-3.78	2.75-3.39	3.06-6.73
Mercury							
Mean	0.25	0.13	0.25	0.38	0.21	0.33	0.03
n	2	4	6	2	5	5	10
Std dev		0.09	0.18		0.06	0.27	0.01
Range	0.23-0.27	0.04-0.27	0.08-0.32	0.13-0.63	0.12-0.29	0.10-0.84	0.02-0.05
Arsenic							
Mean	12.40		4.01	12.51			
n	2		7	2			
Std dev			0.47				
Range	11.4-13.3		3.24-4.81	6.07-18.9			

Table 6 Metal concentrations in **Haddock** (*Melanogrammus aeglefinus*) from individual areas (mg/kg wet weight)

	Viking	Forties	Central	Shetland	Orkney	Buchan	Moray Firth	North Minch
Cadmium								
Mean	<0.001	<0.001	<0.001	0.002	<0.001	0.001	<0.001	<0.001
n	10	10	10	10	10	10	10	10
Std dev	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-0.005	<0.001-<0.001	<0.001-0.003	<0.001-<0.001	<0.001-<0.001
Copper								
Mean	0.12	0.10	0.08	0.30	<0.02	0.14	0.06	0.12
n	10	10	10	10	10	10	10	10
Std dev	0.03	0.06	0.02	0.08	0.00	0.04	0.03	0.06
Range	0.08-0.17	<0.02-0.25	0.05-0.13	0.17-0.42	<0.02-<0.02	0.09-0.21	<0.02-0.10	0.05-0.28
Lead								
Mean	<0.01	<0.02	<0.02	0.01	<0.02	0.01	<0.02	<0.02
n	10	10	10	10	10	10	10	10
Std dev	0.01	<0.02	<0.02	<0.02	<0.02	0.01	<0.02	<0.02
Range	<0.01- 0.03	<0.02-<0.02	<0.02-<0.02	<0.01 -0.01	<0.02-<0.02	<0.01-0.03	<0.02-<0.02	<0.02-<0.02
Zinc								
Mean	3.26	3.07	2.97	4.77	3.14	3.44	3.57	2.14
n	10	10	10	10	10	10	10	10
Std dev	0.35	0.40	0.23	0.76	0.38	1.34	0.62	0.43
Range	2.89-4.16	<0.01-3.57	2.56-3.42	3.88-6.51	2.58-4.07	2.69-7.36	2.16-4.36	1.74-3.32
Mercury								
Mean	0.06	0.05	0.10	0.04	0.05	0.04	0.06	0.03
n	8	10	10	10	10	8	10	10
Std dev	0.03	0.02	0.04	0.01	0.01	0.01	0.01	0.01
Range	0.02-0.09	0.02-0.10	0.03-0.16	0.02-0.06	0.03-0.07	0.02-0.05	0.04 -0.09	0.01 -0.06
Arsenic								
Mean	6.15			7.05		12.90		
n	10			10		10		
Std dev	2.38			3.36		7.31		
Range	1.85-11.0			3.24-15.5		0.04-28.1		

Table 7 Metal concentrations in **Hake** (*Merluccius merluccius*) from individual areas (mg/kg wet weight)

	Shetland	North Minch	South Minch	Hebrides	Clyde
Cadmium					
Mean	<0.001	<0.001	<0.001	<0.001	<0.001
n	8	22	12	7	20
Std dev	<0.001	<0.001	<0.001	<0.001	0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-0.005
Copper					
Mean	0.12	0.14	0.16	0.22	0.11
n	8	22	12	7	20
Std dev	0.04	0.03	0.02	0.07	0.06
Range	0.04-0.16	0.10-0.20	0.13-0.20	0.16-0.39	0.03-0.26
Lead					
Mean	<0.01	<0.01	<0.01	0.01	0.02
n	8	22	12	7	20
Std dev	<0.01	0.01	0.01	0.02	0.02
Range	<0.01-<0.01	<0.01-0.02	<0.01-0.02	<0.01-0.05	<0.01-0.07
Zinc					
Mean	3.52	3.21	3.58	4.15	3.43
n	8	22	12	7	20
Std dev	0.26	0.53	0.34	0.35	1.08
Range	2.99-3.77	2.02-3.72	3.16-4.48	3.83-4.96	1.61-5.90
Mercury					
Mean	0.02	0.02	0.02	0.08	0.03
n	8	22	12	7	19
Std dev	0.01	0.01	0.01	0.09	0.01
Range	0.01-0.04	0.01-0.03	0.02 -0.04	0.02-0.28	0.01-0.06
Arsenic					
Mean	1.52	1.54	1.24	<0.03	1.61
n	7	22	12	7	20
Std dev	0.32	0.41	0.44	0.03	0.23
Range	1.04-2.08	1.00-2.36	0.76-2.39	<0.03-0.08	1.20-2.28

Table 8 Metal concentrations in **Herring** (*Clupea harengus*) from individual areas (mg/kg wet weight)

	North Minch	South Minch	Clyde
Cadmium			
Mean	<0.001	<0.001	<0.001
n	6	10	10
Std dev	<0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001
Copper			
Mean	0.29	0.51	0.79
n	6	10	10
Std dev	0.14	0.22	0.34
Range	0.10-0.56	0.30-0.93	0.24-1.39
Lead			
Mean	<0.02	<0.02	<0.02
n	6	10	10
Std dev	<0.02	<0.02	<0.02
Range	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02
Zinc			
Mean	6.37	6.40	6.10
n	6	10	10
Std dev	1.61	1.79	1.85
Range	4.05-8.89	4.19-10.83	3.85-9.27
Mercury			
Mean	0.01	0.09	0.04
n	6	10	10
Std dev	<0.01	0.04	0.02
Range	<0.01-<0.01	0.04-0.13	0.01-0.07

Table 9 Metal concentrations in **Lemon sole** (*Microstomus kitt*) from individual areas (mg/kg wet weight)

	Forties	Central	Shetland	Buchan	Moray Firth	North Minch
Cadmium						
Mean	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
n	9	10	6	10	10	10
Std dev	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001
Copper						
Mean	1.05	0.05	0.02	0.01	0.02	0.02
n	9	10	6	10	10	10
Std dev	2.41	0.02	0.01	0.01	0.03	0.02
Range	0.06-7.85	<0.02-0.10	<0.02-0.04	<0.02-0.02	<0.02-0.12	<0.02-0.07
Lead						
Mean	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
n	9	10	6	10	10	10
Std dev	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Range	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02
Zinc						
Mean	3.46	2.84	2.40	2.59	3.39	3.03
n	8	10	6	10	10	10
Std dev	0.25	0.35	0.27	0.30	0.26	0.35
Range	3.21-4.02	2.40-3.42	2.14-2.94	1.92-3.05	2.94-3.82	2.50-3.81
Mercury						
Mean	0.16	0.17	0.09	0.12	0.26	0.03
n	9	10	6	10	10	10
Std dev	0.10	0.11	0.04	0.03	0.12	0.02
Range	0.03-0.36	0.05-0.37	0.04-0.16	0.07-0.17	<0.01-0.50	0.01-0.08

Table 10 Metal concentrations in **Ling** (*Molva molva*) from individual areas (mg/kg wet weight)

	Viking	Forties	Shetland	North Minch	South Minch
Cadmium					
Mean	<0.001	0.001	0.001	0.001	<0.001
n	3	6	2	10	4
Std dev	0.001	0.001		<0.001	<0.001
Range	<0.001-0.001	<0.001-0.003	0.001-0.001	<0.001-0.001	<0.001-<0.001
Copper					
Mean	0.19	0.16	0.14	0.16	0.04
n	3	6	2	10	4
Std dev	0.03	0.05		0.05	0.02
Range	0.16-0.23	0.05-0.21	0.12-0.16	0.11-0.27	0.02-0.07
Lead					
Mean	0.03	0.02	<0.01	0.01	<0.02
n	3	6	2	10	4
Std dev	0.05	0.04		0.01	<0.02
Range	<0.01-0.10	<0.01-0.10	<0.01-<0.01	<0.01-0.02	<0.02-<0.02
Zinc					
Mean	5.17	5.06	3.96	4.22	3.63
n	3	6	2	10	4
Std dev	0.79	0.61		1.49	0.48
Range	4.57-6.28	4.16-5.76	3.59-4.32	<0.10-5.38	3.04-4.27
Mercury					
Mean	0.05	0.07	0.04	0.13	0.11
n	3	6	2	10	4
Std dev	0.02	0.03		0.18	0.03
Range	0.04-0.08	0.03-0.12	0.03-0.05	0.04-0.14	0.06-0.15
Arsenic					
Mean	6.01	4.94	3.06	2.84	
n	3	6	2	10	
Std dev	3.99	1.89		1.09	
Range	2.74-11.6	2.03-7.29	2.54-3.57	1.30-5.04	

Table 11 Metal concentrations in **Mackerel** (*Scomber scombrus*) from individual areas (mg/kg wet weight)

	Viking	Shetland	North Minch
Cadmium			
Mean	0.003	<0.001	0.006
n	11	10	9
Std dev	0.002	<0.001	0.002
Range	0.001-0.007	<0.001-<0.001	0.002-0.010
Copper			
Mean	1.27	0.48	1.01
n	11	10	9
Std dev	0.39	0.26	0.26
Range	0.74-2.11	0.12-1.10	0.60-1.38
Lead			
Mean	<0.01	<0.02	<0.01
n	11	10	9
Std dev	<0.02	<0.02	0.01
Range	<0.01-0.01	<0.02-<0.02	<0.01-0.01
Zinc			
Mean	4.77	4.51	5.36
n	11	10	9
Std dev	0.80	0.67	0.82
Range	4.13-6.77	3.52-5.68	4.27-6.99
Mercury			
Mean	0.03	0.03	0.05
n	11	10	9
Std dev	0.01	0.01	0.01
Range	0.02-0.04	0.02-0.05	0.04-0.05
Arsenic			
Mean	5.77		1.20
n	11		9
Std dev	8.68		0.36
Range	0.96-31.3		0.57-1.81

Table 12 Metal concentrations in **Megrim** (*Lepidorhombus whiffiagonis*) from individual areas (mg/kg wet weight)

	Shetland	South Minch	Hebrides
Cadmium			
Mean	<0.001	0.001	<0.001
n	5	12	10
Std dev	<0.001	0.002	<0.001
Range	<0.001-<0.001	<0.001-0.007	<0.001-<0.001
Copper			
Mean	0.12	0.09	0.18
n	5	12	10
Std dev	0.02	0.03	0.19
Range	0.09-0.15	0.05-0.15	0.08 -0.75
Lead			
Mean	0.01	0.03	<0.01
n	5	12	10
Std dev	0.01	0.09	0.01
Range	<0.01-0.03	<0.01-0.34	<0.01-0.01
Zinc			
Mean	3.60	3.03	4.55
n	5	12	10
Std dev	0.32	0.66	0.85
Range	3.08-4.02	1.89-3.98	3.58-6.17
Mercury			
Mean	0.03	0.02	
n	5	12	
Std dev	<0.01	<0.01	
Range	0.03-0.04	0.02-0.03	
Arsenic			
Mean	2.95	3.48	2.19
n	5	12	10
Std dev	0.96	0.57	1.81
Range	1.38-4.27	2.72-4.39	<0.03-2.87

Table 13 Metal concentrations in **Mussel** (*Mytilus edulis*) from individual areas (mg/kg wet weight)

	Orkney	Moray Firth	North Minch	South Minch	Hebrides
Cadmium					
Mean	0.125	0.101	0.095	0.100	0.109
n	4	1	2	4	1
Std dev	0.047			0.008	
Range	0.086-0.205	0.101-0.101	0.085-0.104	0.090-0.113	0.109-0.109
Copper					
Mean	0.70	0.92	0.61	7.74	1.01
n	4	1	2	4	1
Std dev	0.17			11.55	
Range	0.50-0.92	0.92 -0.92	0.61-0.62	0.93-27.74	1.01-1.01
Lead					
Mean	0.51	0.35	0.16	0.17	0.19
n	4	1	2	4	1
Std dev	0.20			0.06	
Range	0.24-0.80	0.35-0.35	0.10-0.21	0.08-0.24	0.19-0.19
Zinc					
Mean	9.41	9.00	4.09	77.70	11.60
n	4	1	2	4	1
Std dev	1.18			123.00	
Range	7.81-10.76	9.00-9.00	3.23-4.94	5.44-290	11.6 -11.6
Mercury					
Mean	0.01	0.01	0.02	0.01	0.01
n	4	1	2	4	1
Std dev	0.00			0.01	
Range	0.01-0.01	0.01-0.01	0.01-0.02	0.01-0.02	0.01-0.01
Arsenic					
Mean	1.70	1.42	2.14	1.85	28.40
n	4	1	2	4	1
Std dev	0.15			0.35	
Range	1.53-1.94	1.42-1.42	1.95-2.33	1.38-2.20	28.4-28.4

Table 14

Metal concentrations in **Norway lobster** (*Nephrops norvegicus*) from individual areas (mg/kg wet weight)

	South Minch	Clyde
Cadmium		
Mean	<0.001	<0.001
n	1	2
Std dev		
Range	<0.001-<0.001	<0.001-<0.001
Copper		
Mean	2.93	4.02
n	1	2
Std dev		
Range	2.93-2.93	3.97-4.08
Lead		
Mean	<0.02	<0.02
n	1	2
Std dev		
Range	<0.02 -<0.02	<0.02-<0.02
Zinc		
Mean	0.10	13.20
n	1	2
Std dev		
Range	0.10 -0.10	13.1-13.3
Mercury		
Mean	0.09	0.08
n	4	2
Std dev	0.04	
Range	0.04-0.14	0.07-0.09

Table 15 Metal concentrations in **Oyster** (*Ostrea edulis*) from individual areas (mg/kg wet weight)

	North Minch	South Minch	Clyde
Cadmium			
Mean	0.089	0.083	0.079
n	2	2	2
Std dev			
Range	0.087-0.090	0.072-0.094	0.075-0.083
Copper			
Mean	7.80	3.04	8.52
n	2	2	2
Std dev			
Range	6.67-8.93	0.91-5.16	1.01-16.0
Lead			
Mean	0.07	0.19	0.06
n	2	2	2
Std dev			
Range	0.06 -0.07	0.16-0.21	0.05-0.07
Zinc			
Mean	156	87.0	161
n	2	2	2
Std dev			
Range	154-157	10.6-163	10.5-312
Mercury			
Mean	1.82	1.50	1.38
n	2	2	2
Std dev			
Range	1.67-1.97	1.28-1.71	0.81-1.95

Table 16 Metal concentrations in **Plaice** (*Pleuronectes platessa*) from individual areas (mg/kg wet weight)

	Forties	Central	Shetland	Orkney	Buchan
Cadmium					
Mean	0.002	0.001	0.002	0.001	<0.001
n	15	9	11	10	12
Std dev	0.004	0.002	0.003	0.002	<0.001
Range	<0.001-0.014	<0.001-0.006	<0.001-0.008	<0.001-0.005	<0.001-<0.001
Copper					
Mean	0.08	0.14	0.08	0.19	0.16
n	15	9	11	10	12
Std dev	0.03	0.02	0.02	0.06	0.06
Range	0.04-0.13	0.10-0.19	0.03-0.12	0.13-0.32	0.11-0.37
Lead					
Mean	0.01	0.01	0.01	0.02	0.05
n	15	9	11	10	12
Std dev	0.10	0.01	0.01	0.01	0.03
Range	<0.01-0.04	<0.01-0.02	<0.01-0.03	0.01-0.05	0.02-0.12
Zinc					
Mean	4.81	5.14	4.31	6.51	5.08
n	15	9	11	10	12
Std dev	0.61	0.50	0.76	1.00	1.78
Range	4.05-6.38	4.39-5.99	2.76-5.61	4.94 -8.36	<0.10-7.55
Mercury					
Mean	0.06	0.03	0.03	0.05	0.04
n	15	9	11	9	11
Std dev	0.05	0.01	0.01	0.02	0.02
Range	<0.01-0.19	0.01-0.05	0.01-0.06	0.02-0.08	0.02-0.09
Arsenic					
Mean	13.90	18.70	8.28	8.60	11.70
n	15	9	11	10	12
Std dev	15.40	12.40	2.36	10.20	10.00
Range	0.10-52.8	5.47-43.1	4.53-11.7	0.27-30.8	0.24-31.7

Table 17 Metal concentrations in **Saithe** (*Pollachius virens*) from individual areas (mg/kg wet weight)

	Forties	Viking	Shetland	North Minch
Cadmium				
Mean	<0.001	<0.001	<0.001	<0.001
n	3	5	10	10
Std dev	<0.001	<0.001	<0.001	<0.001
Range	<0.001-0.001	<0.001-<0.001	<0.001-0.001	<0.001-<0.001
Copper				
Mean	0.59	0.28	0.34	0.25
n	3	5	10	10
Std dev	0.40	0.35	0.07	0.20
Range	0.21-1.15	0.07-0.97	0.19-0.45	0.08 -0.75
Lead				
Mean	<0.01	<0.01	<0.01	<0.02
n	3	5	10	10
Std dev	<0.01	<0.01	<0.01	<0.02
Range	<0.01-<0.01	<0.01-<0.01	<0.01-<0.01	<0.02-<0.02
Zinc				
Mean	4.51	5.74	5.48	4.08
n	3	5	10	10
Std dev	0.69	0.82	0.59	0.32
Range	3.54-5.05	4.49-6.80	4.92-6.58	3.62-4.64
Mercury				
Mean	0.12	0.05	0.03	0.07
n	3	5	10	10
Std dev	0.05	0.02	0.01	0.02
Range	0.06-0.18	0.03 -0.08	0.02-0.04	0.03-0.08
Arsenic				
Mean	1.83	2.44	2.22	
n	3	5	10	
Std dev	0.15	1.25	0.37	
Range	1.68-2.03	0.88-4.16	1.64-2.80	

Table 18 Metal concentrations in **Scallop** (*Pecten maximus*) from individual areas (mg/kg wet weght)

	Shetland	Buchan	Clyde
Cadmium			
Mean	0.103	0.177	0.048
n	8	2	7
Std dev	0.109		0.033
Range	0.022-0.215	0.093-0.260	0.022-0.117
Copper			
Mean	0.72	0.52	1.13
n	8	2	7
Std dev	0.58		1.86
Range	0.20-1.71	0.47-0.57	0.09 -5.67
Lead			
Mean	0.05	0.14	0.07
n	8	2	7
Std dev	0.06		0.08
Range	<0.01-0.18	0.10-0.18	0.02-0.25
Zinc			
Mean	18.2	23.58	11.6
n	8	2	7
Std dev	15.9		14.0
Range	<0.10-49.4	20.7-26.5	<0.10-41.9
Mercury			
Mean	0.04	0.01	0.03
n	8	2	7
Std dev	0.26		0.01
Range	0.02 -0.09	0.01-0.01	0.02-0.05
Arsenic			
Mean	1.50	0.85	3.06
n	8	2	7
Std dev	0.56		1.14
Range	0.70-2.34	0.67-1.02	1.31-5.26

Table 19 Metal concentrations in **Skate** (*Raja naevus*) from individual areas (mg/kg wet weight)

	Shetland	Orkney	Buchan	North Minch
Cadmium				
Mean	<0.001	<0.001	<0.001	0.004
n	5	6	8	10
Std dev	<0.001	<0.001	<0.001	0.004
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-0.012
Copper				
Mean	0.10	0.05	0.10	0.15
n	5	6	8	10
Std dev	0.03	0.02	0.07	0.04
Range	0.05-0.15	0.02-0.08	0.02-0.13	0.10-0.24
Lead				
Mean	<0.02	<0.02	<0.02	0.01
n	5	6	8	10
Std dev	<0.02	<0.02	<0.02	0.01
Range	<0.02-<0.02	<0.02-<0.02	<0.02-<0.02	<0.01-0.02
Zinc				
Mean	3.43	3.25	3.80	3.84
n	5	6	8	10
Std dev	0.67	0.46	0.62	0.34
Range	2.29-4.17	2.39-3.89	3.07-4.82	3.43-4.53
Mercury				
Mean	0.09	0.03	0.07	0.04
n	5	6	8	9
Std dev	0.06	0.02	0.06	0.24
Range	0.04-0.20	0.01-0.06	0.02-0.22	0.01-0.09
Arsenic				
Mean				14.6
n				9
Std dev				2.79
Range				11.2-20.3

Table 20 Metal concentrations in **Squid** (*Loligo forbesi*) from individual areas (mg/kg wet weight)

	North Minch	Hebrides	Clyde
Cadmium			
Mean	<0.001	0.068	0.011
n	9	10	6
Std dev	<0.001	0.012	0.005
Range	<0.001-<0.001	0.056 -0.082	<0.001-0.015
Copper			
Mean	0.92	19.06	1.39
n	9	10	6
Std dev	0.33	6.39	0.25
Range	0.79-1.2	3.74-28.63	1.04 -1.82
Lead			
Mean	<0.01	0.05	<0.01
n	9	10	5
Std dev	0.01	0.05	0.01
Range	<0.01-0.02	<0.01-0.19	<0.01-0.01
Zinc			
Mean	9.76	12.8	10.6
n	9	10	6
Std dev	0.61	0.68	0.78
Range	8.64-10.7	12.0-14.5	9.43-11.9
Mercury			
Mean	0.03	0.05	0.02
n	8	10	6
Std dev	0.01	<0.01	<0.01
Range	0.03-0.04	0.05-0.06	0.02-0.03
Arsenic			
Mean	7.28	11.50	4.91
n	9	10	6
Std dev	1.19	0.89	0.28
Range	5.59-9.25	10.4-13.8	4.51-5.43

Table 21 Metal concentrations in **Torsk** (*Brosme brosme*) from individual areas (mg/kg wet weight)

	Viking	Forties
Cadmium		
Mean	<0.001	<0.001
n	5	6
Std dev	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001
Copper		
Mean	0.12	0.15
n	5	6
Std dev	0.02	0.06
Range	0.11-0.15	0.11-0.27
Lead		
Mean	<0.01	0.01
n	5	6
Std dev	<0.02	0.01
Range	<0.01-<0.01	<0.01-0.01
Zinc		
Mean	4.16	4.32
n	5	6
Std dev	0.47	0.72
Range	3.46-4.71	3.41-5.14
Mercury		
Mean	0.10	0.12
n	5	6
Std dev	0.05	0.04
Range	0.06-0.19	0.08-0.15
Arsenic		
Mean	9.29	2.79
n	5	6
Std dev	0.05	0.72
Range	8.48-9.85	1.58-3.63

Table 22 Metal concentrations in **Turbot** (*Scophthalmus maximus*) from individual areas (mg/kg wet weight)

	Forties	Central	Shetland	Buchan
Cadmium				
Mean	<0.001	<0.001	<0.001	<0.001
n	3	6	4	5
Std dev	<0.001	<0.001	<0.001	<0.001
Range	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001	<0.001-<0.001
Copper				
Mean	0.08	0.06	0.04	0.11
n	3	6	4	5
Std dev	0.02	0.06	0.06	0.03
Range	0.06-0.11	<0.02-0.13	<0.02-0.14	0.09-0.17
Lead				
Mean	<0.01	<0.01	<0.01	<0.01
n	3	6	4	5
Std dev	<0.01	0.01	<0.01	<0.01
Range	<0.01-<0.01	<0.01-0.02	<0.01-0.01	<0.01-0.01
Zinc				
Mean	4.71	1.86	1.73	4.99
n	3	6	4	5
Std dev	0.36	2.63	2.99	1.31
Range	4.27-5.14	<0.10-5.67	<0.10-6.91	3.72-7.45
Mercury				
Mean	0.03	0.07	0.10	0.06
n	3	6	4	3
Std dev	0.02	0.02	0.08	0.01
Range	0.01-0.05	0.05-0.10	0.03-0.23	0.05-0.07
Arsenic				
Mean	3.78	5.75	5.30	3.73
n	3	6	4	5
Std dev	0.34	2.51	2.07	2.54
Range	3.48-4.25	3.09-10.9	3.15-8.00	0.30-6.91

Table 23 Metal concentrations in **Whiting** (*Merlangius merlangus*) from individual areas (mg/kg wet weight)

	Viking	Forties	Central	Shetland	Buchan	North Minch	South Minch
Cadmium							
Mean	0.002	<0.001	0.001	0.002	0.001	<0.001	<0.001
n	14	10	9	10	9	10	10
Std dev	0.003	<0.001	0.001	0.002	0.001	<0.001	<0.001
Range	<0.001-0.014	<0.001-0.001	<0.001-0.001	<0.001-0.009	<0.001-0.004	<0.001-<0.001	<0.001-<0.001
Copper							
Mean	0.18	0.12	0.14	0.18	0.17	0.08	0.13
n	14	10	9	10	9	10	10
Std dev	0.03	0.04	0.05	0.05	0.03	0.04	0.05
Range	0.13-0.23	0.09-0.17	0.08-0.22	0.10-0.31	0.13-0.20	0.04-0.16	0.08-0.25
Lead							
Mean	<0.01	<0.01	<0.01	0.02	0.01	<0.02	<0.02
n	14	10	9	10	9	10	10
Std dev	0.01	<0.02	<0.02	0.03	<0.02	<0.02	<0.02
Range	<0.01-0.02	<0.01-<0.01	<0.01-0.01	<0.01-0.11	<0.01-0.08	<0.02-<0.02	<0.02-<0.02
Zinc							
Mean	3.88	3.58	4.05	3.92	3.50	3.67	3.62
n	14	10	9	10	9	10	10
Std dev	0.34	0.60	0.27	0.71	0.53	0.57	0.27
Range	3.18-4.43	2.52-4.87	3.60-4.50	2.60-5.16	2.18 -4.12	3.08-5.06	3.21-4.04
Mercury							
Mean	0.03	0.08	0.04	0.04	0.04	0.04	0.04
n	14	10	9	10	9	10	10
Std dev	0.01	0.10	0.02	0.01	0.02	0.01	0.01
Range	0.02-0.04	0.02-0.37	0.02-0.09	0.02-0.06	0.02-0.09	0.02-0.05	0.02-0.06
Arsenic							
Mean	2.29	1.09	4.26	3.52	10.20		
n	14	10	9	10	6		
Std dev	0.81	0.57	0.94	2.26	6.95		
Range	1.09-4.64	0.50-2.00	2.96-5.70	1.83-10.1	1.62-22.2		

Table 24 Summary of metal concentrations in fish and shellfish from Scottish waters (mg/kg wet weight)

Angler			Catfish			Cod			Dogfish		
Cadmium	mean	<0.001	Cadmium	mean	<0.001	Cadmium	mean	<0.001	Cadmium	mean	<0.001
	range	<0.001-<0.001		range	<0.001-<0.001		range	<0.001-<0.001		range	<0.001-0.001
Copper	mean	0.10	Copper	mean	0.18	Copper	mean	0.10	Copper	mean	0.28
	range	<0.02-1.20		range	0.11-0.32		range	<0.02-0.36		range	0.03-1.22
Lead	mean	<0.02	Lead	mean	<0.01	Lead	mean	<0.02	Lead	mean	<0.02
	range	<0.02-<0.02		range	<0.01-0.16		range	<0.02-<0.02		range	<0.01-0.03
Zinc	mean	4.49	Zinc	mean	7.17	Zinc	mean	3.65	Zinc	mean	3.76
	range	3.12-9.34		range	5.08-10.3		range	2.93-9.19		range	1.61-10.5
Mercury	mean	0.06	Mercury	mean	0.11	Mercury	mean	0.10	Mercury	mean	0.22
	range	0.01-0.11		range	0.02-0.39		range	0.02-0.42		range	0.02-0.84
Arsenic	mean		Arsenic	mean	5.51	Arsenic	mean		Arsenic	mean	9.62
	range			range	2.67-9.18		range			range	3.24-18.9
Haddock			**Hake**			**Herring**			**Lemon Sole**		
Cadmium	mean	<0.001	Cadmium	mean	<0.001	Cadmium	mean	<0.001	Cadmium	mean	<0.001
	range	<0.001-0.005		range	<0.001-0.005		range	<0.001-<0.001		range	<0.001-<0.001
Copper	mean	0.11	Copper	mean	0.15	Copper	mean	0.53	Copper	mean	0.20
	range	<0.02-0.42		range	0.03-0.39		range	0.10-1.39		range	<0.02-7.85
Lead	mean	<0.01	Lead	mean	<0.01	Lead	mean	<0.02	Lead	mean	<0.02
	range	<0.01-0.03		range	<0.01-0.07		range	<0.02-<0.02		range	<0.02-<0.02
Zinc	mean	3.30	Zinc	mean	3.58	Zinc	mean	6.29	Zinc	mean	2.95
	range	<0.01-7.36		range	1.61-5.90		range	3.85-10.83		range	1.92-4.02
Mercury	mean	0.12	Mercury	mean	0.03	Mercury	mean	0.05	Mercury	mean	0.14
	range	0.01-0.16		range	0.01-0.28		range	<0.01-0.13		range	<0.10-0.50
Arsenic	mean	8.71	Arsenic	mean	1.18	Arsenic	mean		Arsenic	mean	
	range	0.04-28.1		range	<0.03-2.39		range			range	

Ling		
Cadmium	mean	0.001
	range	<0.001-0.003
Copper	mean	0.14
	range	0.02-0.27
Lead	mean	0.01
	range	<0.01-0.10
Zinc	mean	4.41
	range	<0.10-6.28
Mercury	mean	0.08
	range	0.03-0.15
Arsenic	mean	4.21
	range	1.30-11.6

Mackerel		
Cadmium	mean	0.003
	range	<0.001-0.010
Copper	mean	0.92
	range	0.12-2.11
Lead	mean	<0.01
	range	<0.01-0.01
Zinc	mean	4.88
	range	3.52-6.99
Mercury	mean	0.04
	range	0.02-0.05
Arsenic	mean	3.49
	range	0.57-31.3

Megrim		
Cadmium	mean	<0.001
	range	<0.001-0.007
Copper	mean	0.13
	range	0.05-0.75
Lead	mean	0.014
	range	<0.01-0.34
Zinc	mean	3.73
	range	1.89 -6.17
Mercury	mean	0.03
	range	0.02-0.04
Arsenic	mean	2.87
	range	<0.03-4.39

Mussel		
Cadmium	mean	0.106
	range	0.085-0.205
Copper	mean	2.19
	range	0.50-27.74
Lead	mean	0.273
	range	0.08-0.80
Zinc	mean	22.40
	range	3.23-290
Mercury	mean	0.01
	range	0.01-0.02
Arsenic	mean	7.11
	range	1.38-28.4

Norway lobster		
Cadmium	mean	<0.001
	range	<0.001-<0.001
Copper	mean	2.16
	range	2.93-4.08
Lead	mean	<0.02
	range	<0.02-<0.02
Zinc	mean	6.65
	range	0.10-13.3
Mercury	mean	0.09
	range	0.04-0.14
Arsenic	mean	
	range	

Oyster		
Cadmium	mean	0.084
	range	0.072-0.094
Copper	mean	6.45
	range	0.91 -16.0
Lead	mean	0.10
	range	0.05-0.21
Zinc	mean	135
	range	10.6-312
Mercury	mean	1.57
	range	0.81-1.97
Arsenic	mean	
	range	

Plaice		
Cadmium	mean	0.001
	range	<0.001-0.014
Copper	mean	0.13
	range	0.03-0.37
Lead	mean	0.02
	range	<0.01-0.12
Zinc	mean	5.17
	range	<0.10-8.36
Mercury	mean	0.04
	range	<0.01-0.19
Arsenic	mean	12.2
	range	0.10-52.8

Saithe		
Cadmium	mean	<0.001
	range	<0.001-0.001
Copper	mean	0.37
	range	0.07-1.15
Lead	mean	<0.01
	range	<0.01 -<0.02
Zinc	mean	4.95
	range	3.54-6.80
Mercury	mean	0.07
	range	0.02-0.18
Arsenic	mean	2.16
	range	0.88-4.16

Scallop		
Cadmium	mean	0.109
	range	0.022-0.260
Copper	mean	0.79
	range	0.09-5.67
Lead	mean	0.086
	range	<0.01-0.25
Zinc	mean	17.8
	range	<0.10-49.4
Mercury	mean	0.03
	range	0.01-0.09
Arsenic	mean	1.80
	range	0.67-5.26

Skate		
Cadmium	mean	0.001
	range	<0.001 -0.012
Copper	mean	0.10
	range	0.02-0.24
Lead	mean	<0.02
	range	<0.01-0.02
Zinc	mean	3.58
	range	2.29-4.82
Mercury	mean	0.06
	range	0.01-0.22
Arsenic	mean	14.6
	range	11.2-20.3

Squid		
Cadmium	mean	0.030
	range	<0.001-0.082
Copper	mean	7.12
	range	0.79-28.63
Lead	mean	0.02
	range	<0.01-0.19
Zinc	mean	11.0
	range	8.64-14.5
Mercury	mean	0.03
	range	0.02-0.06
Arsenic	mean	7.91
	range	4.51-13.8

Torsk		
Cadmium	mean	<0.001
	range	<0.001 -<0.001
Copper	mean	0.14
	range	0.11-0.27
Lead	mean	<0.01
	range	<0.01-0.01
Zinc	mean	4.24
	range	3.41-5.14
Mercury	mean	0.11
	range	0.06-0.19
Arsenic	mean	6.04
	range	1.58-9.85

Turbot		
Cadmium	mean	<0.001
	range	<0.001-<0.001
Copper	mean	0.07
	range	<0.02-0.17
Lead	mean	<0.01
	range	<0.01-0.02
Zinc	mean	3.32
	range	<0.10 -7.45
Mercury	mean	0.06
	range	0.01-0.23
Arsenic	mean	4.38
	range	0.30-10.9

Whiting		
Cadmium	mean	0.001
	range	<0.001 -0.014
Copper	mean	0.14
	range	0.04-0.31
Lead	mean	<0.01
	range	<0.01-0.11
Zinc	mean	3.75
	range	2.18-5.16
Mercury	mean	0.04
	range	0.02-0.37
Arsenic	mean	4.27
	range	0.50-22.2

Figure 1 Locations of the fishing areas given in Table 1

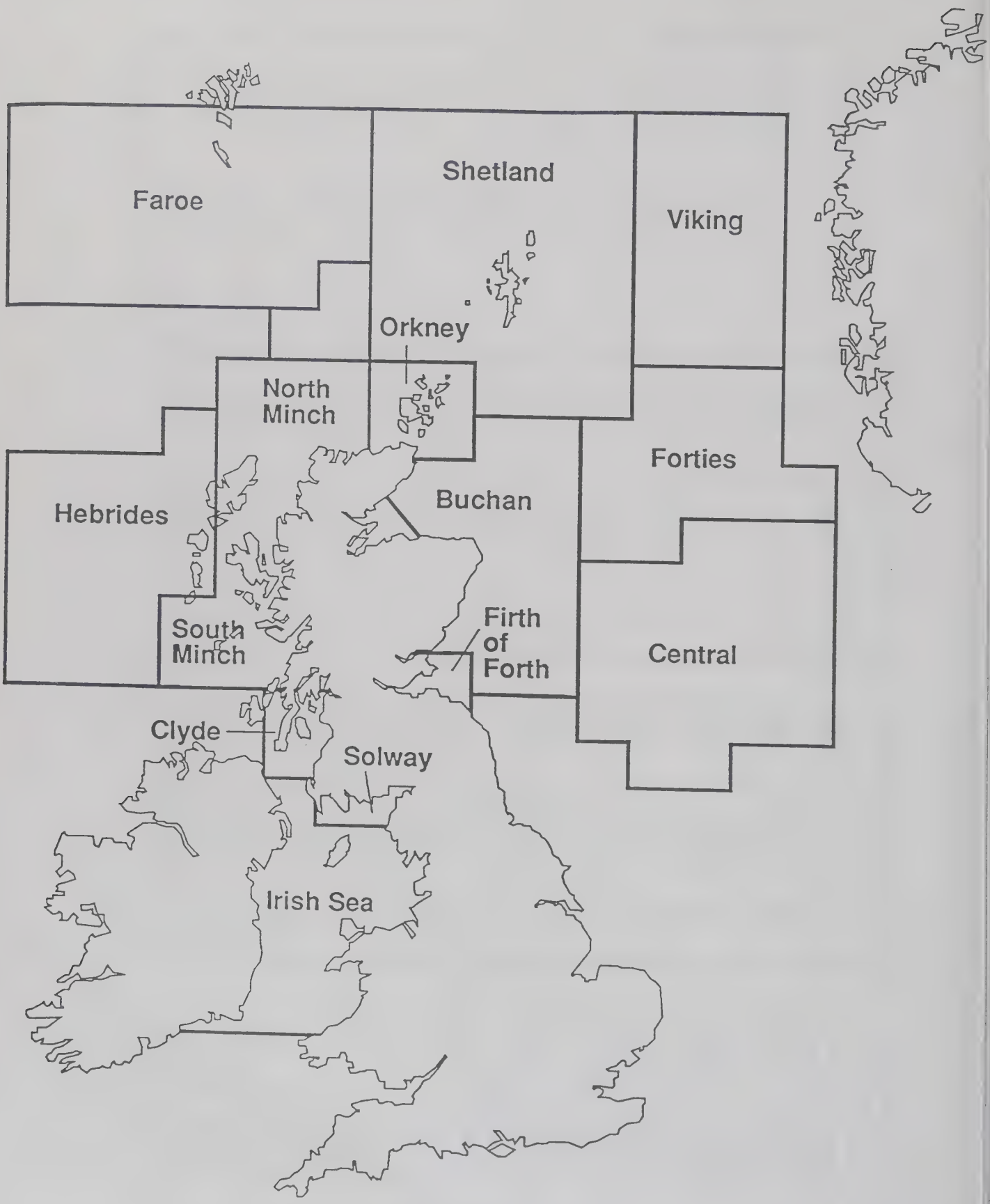


Figure 2 Time series (mean and range) of mercury concentration in Angler (mg/kg wet weight)

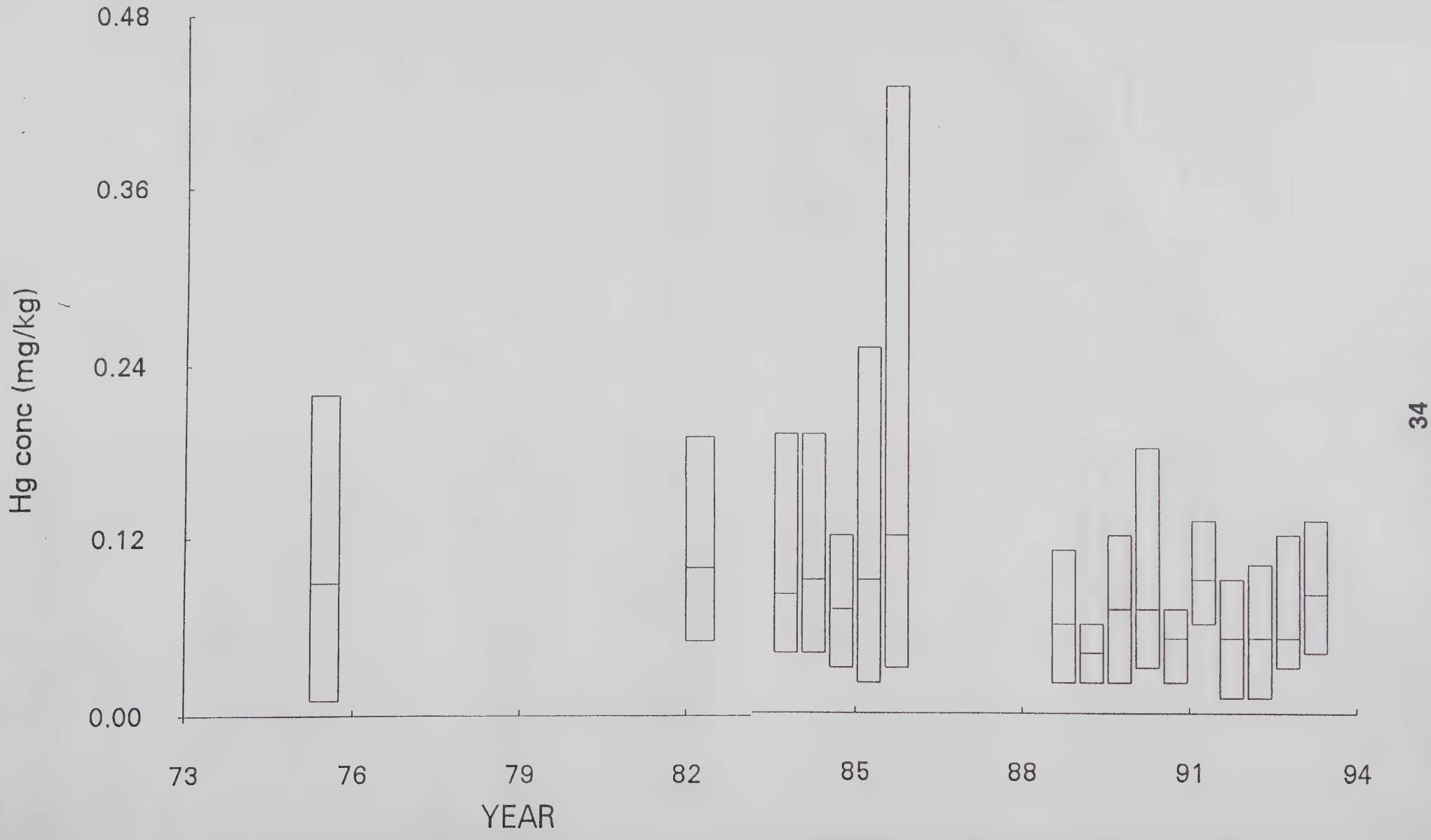
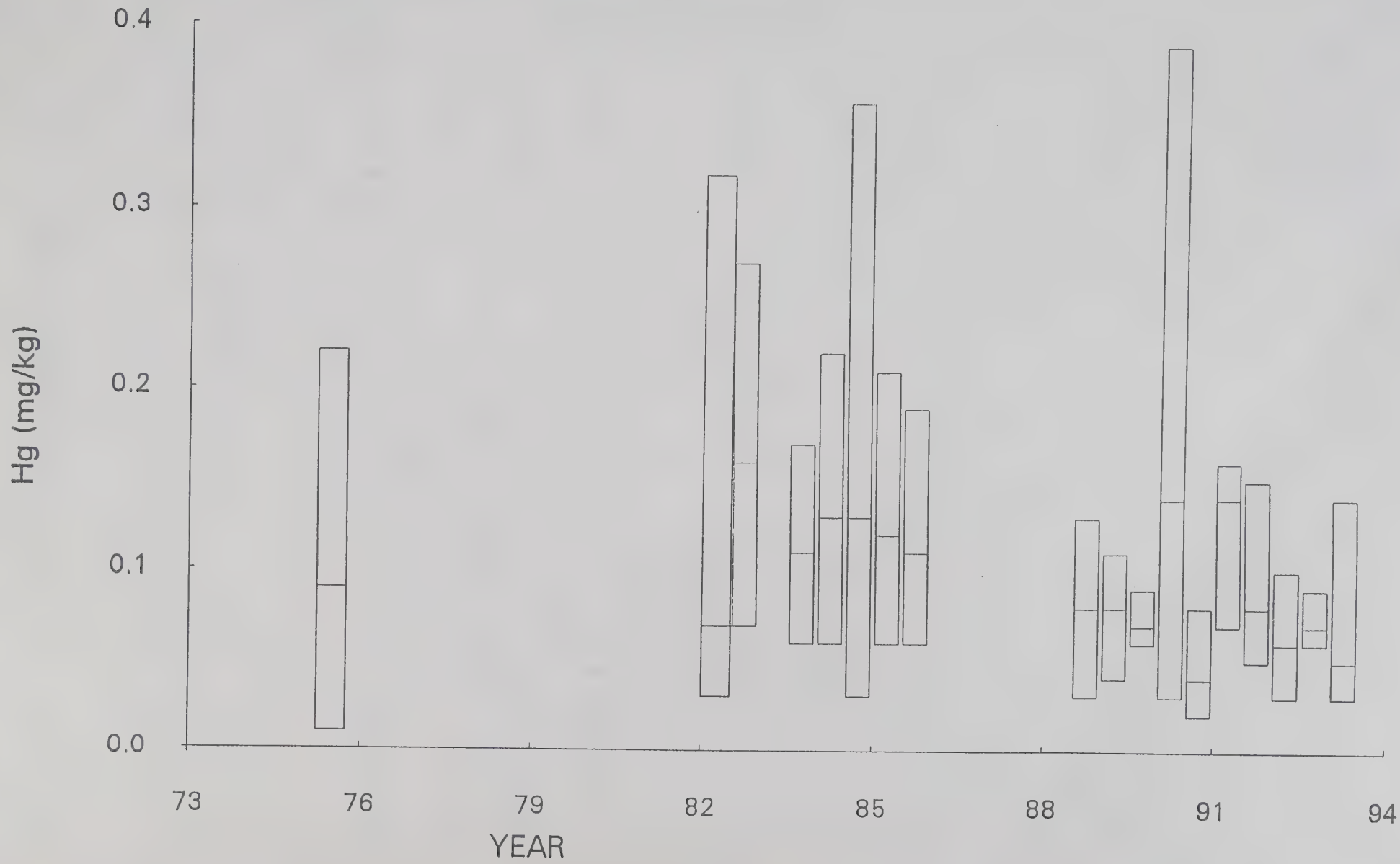


Figure 3 Time series (mean and range) of mercury concentration in Norwegian lobster (mg/kg wet weight)



Appendix

European Standards and Guidelines to Trace Metals in Fish and Shellfish

Taken from MAFF, 1995.

Mercury

Community Decision 93/351 EEC (European Communities 1993) applies to samples of fishery products. This states that the mean total mercury content of the edible parts of fishery products must not exceed 0.5 mg/kg fresh weight, increased to 1.0 mg/kg fresh weight for some species listed in an annex

Cadmium

There are no standards or guidelines in England and Wales for fish flesh. The expected values are <0.2 mg/kg wet weight.

Lead

From the Lead in Food Regulations 1979 (Great Britain-Parliament 1979): Lead in fish should not exceed 2.0 mg/kg wet weight and lead in shellfish 10.0 mg/kg wet weight.

Copper

From the Food Standards Committee's Report on Copper (MAFF 1956) revised recommendations for limits for copper content of food as follows: "levels of copper in food should not exceed 20 mg/kg wet weight (but higher levels in shellfish are permitted if copper is of natural occurrence)".

Zinc

From the Food Standards Committee's Report on Zinc (Ministry of Food 1953) as a guideline: "levels of zinc in food should not exceed 50 mg/kg wet weight (but higher levels are permitted in food which naturally contain more than 50 mg/kg such as herring and shellfish".

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